

Storm Water Flooding Amsterdam, from a quick Scan analyses to an action plan

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Abstract: Dealing with the issue of urban storm water flooding is becoming increasingly urgent. In the Netherlands there are no clear guidelines on the level of acceptance of urban flooding. Based on an accurate DEM, a detailed quick scan tool has been used to assess an extreme storm event in Amsterdam. The resulting flood maps for the whole of the city show where flooding is likely to occur after 60 or 100 mm of rain in one hour, as well as which buildings are at risk.

Based on the results from this mapping study, Amsterdam decided to start a program to make the city rainproof (Amsterdam Rainproof). Part of the program was the validation of the model based on field research. An example of this is the use of data from the extreme storm event that occurred in Amsterdam on 28 July 2014. In this paper several pilots from Amsterdam will address the relevance and effectiveness of the quick scan tool.

Keywords: Storm water flooding; DEM; quick scan

Introduction

Extreme showers cause more and more frequent flooding in Dutch urban areas (Spekkers, 2015). This is due to a combination of climate change, an increase of the paved area and a lack of focus on possible flooding.

In the Netherlands, where the land surface is predominantly flat and where surface water levels often reach ground level, drainage systems are built to prevent water spilling onto the streets at design storms of once every year or once every two years. Flooding of streets has been accepted for more extreme rainfall events. In the past this did not lead directly to the flooding of houses and buildings, as at street level, there was normally additional space available to store water (e.g. between the street kerbs). General design standards for kerb heights, street profiles and floor levels (25 cm above street level) resulted in only rare occurrences of premises being flooded. Unfortunately those design principles have either been neglected or changed over the last three decades (in favor of easier access), resulting in a higher risk of flooding.

It is becoming more apparent that changes in the global climate are having a significant impact on precipitation patterns. From the ten most extreme storm events in the Netherlands between 1951 and 2013, seven were from after 1995 (Kluck, 2013-a, table A1). Because of the changes in rainfall patterns and the experienced more frequent floodings, municipalities have started to enquire whether they need to put more effort into anticipating extreme storms.

The national agency for sewer related issues (Stichting Rioned) expresses that street flooding is something that needs to be accepted and prepared for by designing the streets in such a way that water in the streets does not result in the flooding of premises. And even national policy has stated that cities have to become climate resilient by 2050 and that they should use the upcoming maintenance works on urban space to implement this (Delta Programme, 2015). Also Kluck et al (2013-b) suggest that municipalities should anticipate extreme showers and explains that this should be the work of both water managers and other urban managers.

There is currently no clear standard on how often flooding is acceptable and therefore Dutch municipalities have started investigating how best to deal with this issue. A logical way to approach this problem is, at a minimum, to evaluate what happens following a real extreme storm event and then decide what to do. Blanksby (2011) describes this as way of triage. By analyzing the floodings due to a really extreme event, it is possible to identify the possible problem areas, and to gain more clarity of what actions are needed and in which locations further investigation is needed.

After research and discussions with focus groups that included municipalities, Amsterdam University of Applied Science and Hanze University of Applied Sciences a consensus was agreed upon that a storm event of 60 mm/hour could be used as a first standard level for an extreme event. This was reviewed by different stakeholders, municipalities, provinces, and the local water authority for Amsterdam. This figure is in (Kluck, 2013-a) roughly based on rainfall statistics and arbitrary a return period of once per 100 year has been chosen.

Material and Methods

For a cloudburst, the functioning of the sewer system is in most cases of minor importance when compared with the above ground flow. For extreme events the sewer system is regarded as the minor system and the above ground system as the major system (consisting of streets, parks, and waterways). This becomes clear using the comparison that from a rain event of 60 to 100 mm in one hour only about 20 mm will fit in (and through) the sewer system. The larger part will remain on the surface.

The tool CLOUDS (which is an acronym of Calamity Levels Of Urban Drainage Systems – and in Dutch called WOLK) was used to assess the storm water discharge after a cloudburst in Amsterdam. CLOUDS is used in particular as a quick scan method as municipalities have little time and money available for more in-depth analyses and also, at this stage, detailed, highly accurate results are not normally required. CLOUDS is based on the assumption that the results using only the major drainage system are sufficient and valuable enough for this step. Furthermore, in order to be quick, the model only shows how water flows from high to low, while filling up lower areas with water. This means that flow dynamics are neglected and that only a final situation is presented. This approach has been investigated before (van Dijk et al. 2012) and has proven to be very appealing and efficient as many Dutch municipalities have had their urban drainage systems evaluated this way.

The quick scan is based on only the following readily available data

- Accurate DEM (Digital Elevation Model), which is freely available for the whole of the Netherlands. With 4 points per square meter and a vertical accuracy of several centimeters this provides an excellent insight in the surface elevation. This accuracy is very welcome to model all relevant streets and alleys.
- GIS-map with houses, streets and waterways

The resulting maps show the expected water depths for cloudbursts of 60 and 100 mm in one hour. The maps also show the main stream lines of the above ground water flow.

Results and Conclusions

The use of the maps from CLOUDS gave insight into which locations in Amsterdam are vulnerable to storm water flooding. Amsterdam is too large to show the results in one picture. Therefore the results are presented in an interactive GIS-environment. Because of the assumptions in the simulations, and because this was the first quick scan (and Amsterdam is working on a more accurate assessment), Amsterdam does not want to freely publish those accurate GIS-maps.

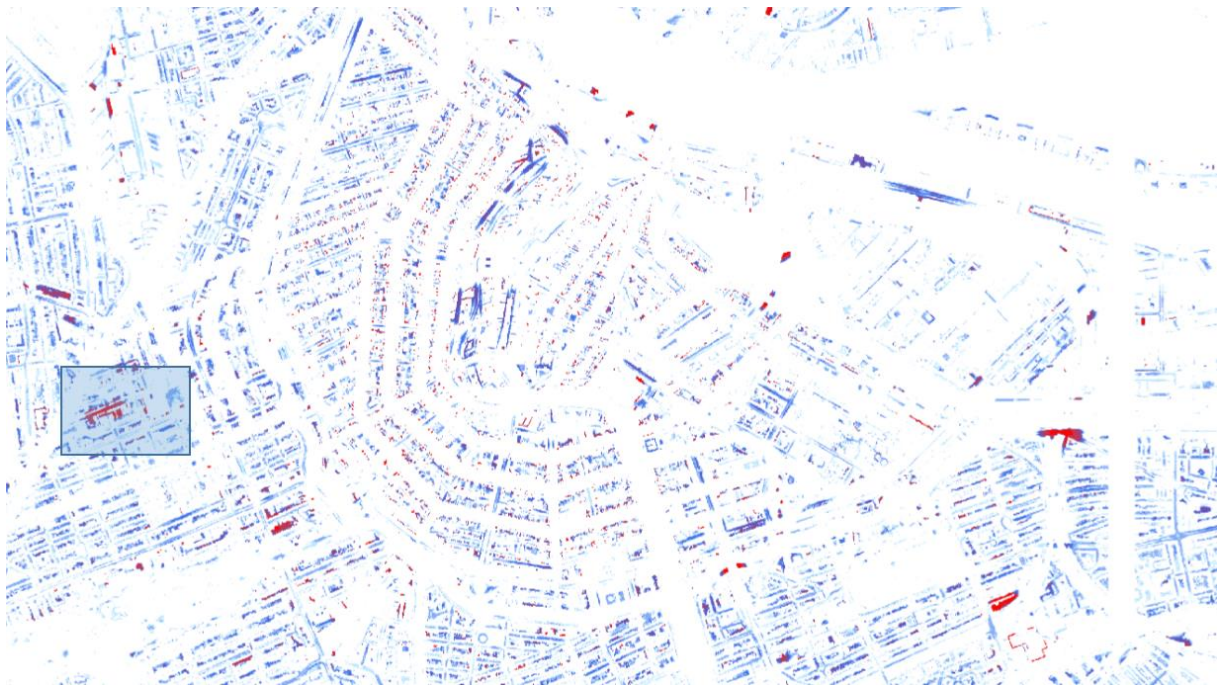


Figure 1: storm water flooding at event of 60mm in 1 hour, red = over 1 m water in depression. The square indicates the zoom area for figure 2.

Figure 1 shows the expected storm water flooding in the centre of Amsterdam for a cloudburst of 60 mm in one hour. The amount of water on ground surface (streets, parks and gardens) is indicated from blue through to red (red being a depression filled with more than 1 m of water). White in the figure x are the houses and the surface water. The structure of the canals is clearly visible. But the maps are more interesting when zoomed in.



Figure 2: Zoom in for computed flooding at Bellemysstraat in Amsterdam for 60 mm in 1 hour.

Only at several specific points water levels build up to more than 50cm like in figure 2. But many houses will get flooded at much lower water levels. In general water will entry at more than 20cm water in the street and at some locations even directly as water builds up.

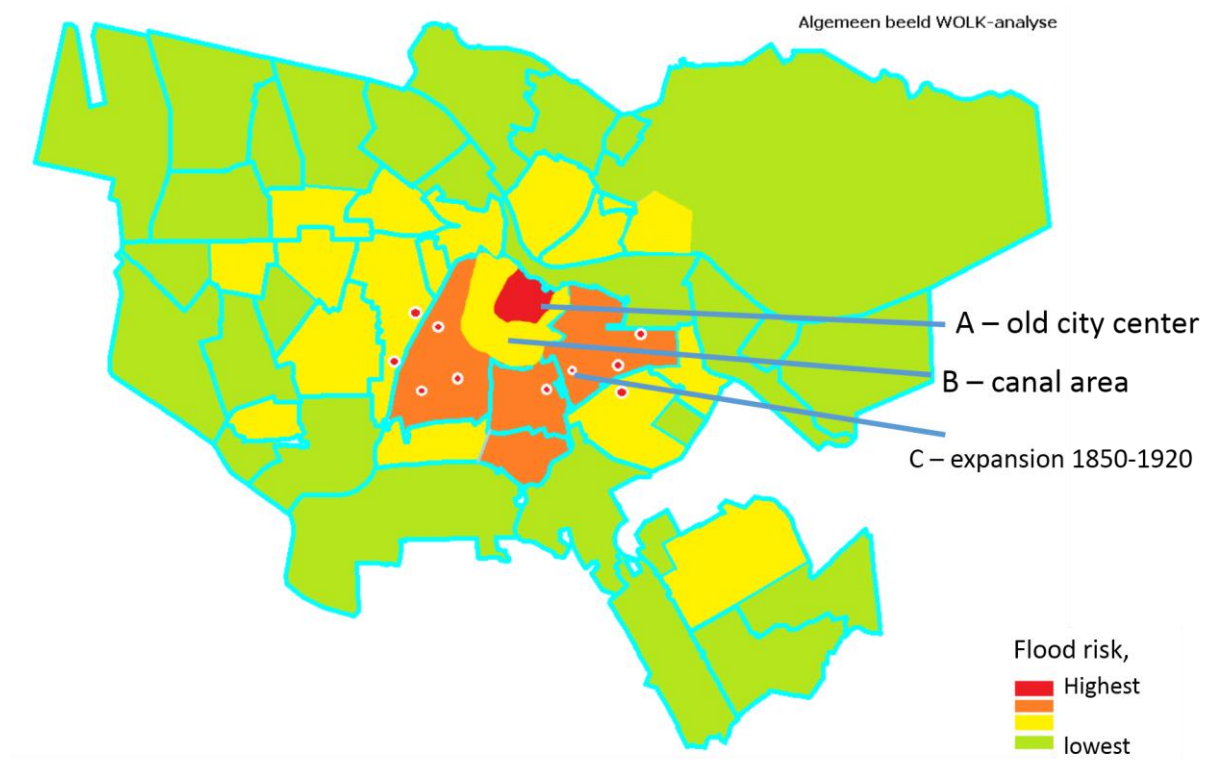


Figure 3: Overall result: red: 35-45% of buildings in danger of flooding, green: 10%

Figure 3 shows how vulnerable houses are to storm water flooding in different districts. Clearly in the old city center the situation seems worst. This is partly because in this part in the past some of the canals have been changed into streets. Those former canals are now vulnerable to flooding because there is no possibility for above ground discharge of rain water. Flooding of the houses in those streets is likely, especially the basements which often are in use as shops or galleries.

The yellow ring surrounding the center is the district with the famous canals (indicated B in the figure). Here storm water flooding is obviously not very likely. Further from the center the risks of flooding appear first higher (area C – city expansion beginning 1900) and then smaller (yellow and green).

The maps from CLOUDS gave Amsterdam valuable insight into possible flood locations for extreme showers. This helped Waternet to start a program to make Amsterdam more rainproof. With help of the results of the quick scan analysis Waternet and the city of Amsterdam in 2014 started a program (conveniently called: Amsterdam Rainproof) to make the city rainproof by 2050. The main aim of this initiative is raising awareness so that rainproof design and development becomes the standard and that water opportunities are always taken (Goedbloed and Claassen, 2014).

Example Betondorp

Betondorp (translation: “concrete village”) is a quiet residential area in Amsterdam with two storey houses. It is part of the lowest polder in Amsterdam at -5.5 m below sea level. This however is not the main issue when considering storm flooding. At a cloudburst, the problem arises that stormwater is not quickly enough discharged to the surface water and that streets remain flooded.

The CLOUDS maps showed flooded streets and long stream lines. The long stream lines indicate that more local solutions are needed. The water doesn’t flood to high levels, which is logical in this flat area. But some streets are definitely at risk and thus more local storage for water is needed.



Figure 4. Situation in Betondorp for 60 mm in one hour. The thick purple line indicates that water flows from south-east eventually to north. Brown indicates high grounds.

For that reason sustainable urban drainage systems have been proposed to increase the water storage in this area and to increase the infiltration rates. Removal of paved areas that are turned into green multifunctional spaces has already taken place and more than 400 green roofs have been constructed. SUDS that are proposed and will be built in the next years are a water square and vegetated swales. The question was at which strategic places should these SUDS be built which is where the surface run of model CLOUDS was used.

Betondorp has been modelled with CLOUDS and was presented with a 3D visualisation. The possible improvements have been discussed with several stakeholders in multiple workshops and fieldtrip in the area (Waternet, 2014). Infiltration tests have been conducted to research the possibility of infiltration in this lowest area of Amsterdam (-5.5 below sea level). Betondorp received the Dutch climate adaptation award 'Peilstok' for implementing cost effective measures as water squares, swales, green roofs and reducing the connected pavement to the sewer system.

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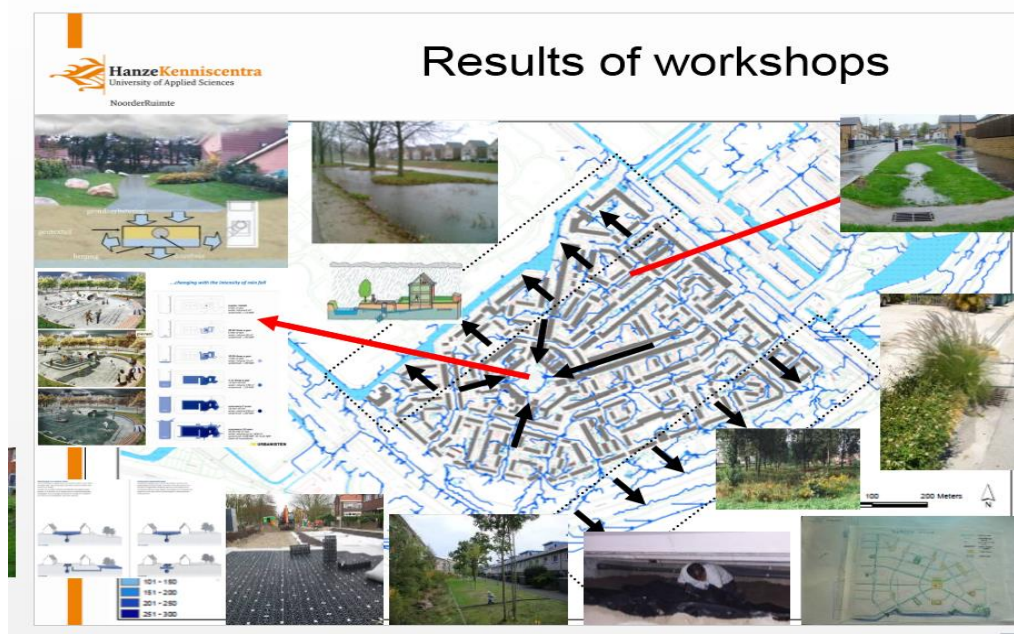


Figure 5 from floodmaps to concrete cost-effective measures with stakeholders in Betondorp)concrete village ☺)



Figure 6: 3D visualization of results CLOUDS in Betondorp



Figure 7: South-side of betondorp before and after measurements

Validation

The results of CLOUDS for Amsterdam have been validated. The city of Amsterdam was unfortunate with a high cloud burst at July 28th 2014, which resulted in flooding of houses and company buildings.

Waternet with help of students from Amsterdam University of Applied Sciences have further checked the results of CLOUDS for specific locations with flooding. Their conclusions were that in general CLOUDS provides the insight in where flooding might be an issue. The quick scan is of course not always fully accurate. The validation showed some locations where the CLOUDS model was not correct. This included locations where even within the $0.5 \times 0.5 \text{ m}^2$ DEM was not accurate enough for modelling a small wall or opening in a wall, or location where surface water was absent, or a location where the date of the DEM (2009) did not fit the date of the building data. Furthermore at some locations (especially locations close to surface water) the sewer discharge is much larger than 20 mm. Having said this, the quick scan provides valuable insight into where a cloud burst might cause problems. In general the CLOUDS showed that most problems are expected in the densest built up areas, which are also the older parts of the city.

Waternet is now participating in developing a more accurate and more complete modelling tool for assessing water flow. With the tool 3Di it is possible to assess the storm water discharge combined with sewer flow for smaller parts of the city at one time. Some smaller parts have been modelled in 3Di.

Those assumptions are valid because it appears that the results are mainly meant for communication, since the local water manager or sewer manager in most cases knows very well that water accumulates at the low spots and from where the water streams from. But most water managers have often difficulty in explaining to the other managers and designers of the urban space that they too have a role in preventing flooding due to extreme showers. The flood maps help to show what happens at extreme events to others.

Conclusions

The use of the maps of CLOUDS gave valuable insight in possible flood locations for extreme showers in Amsterdam. This was a quick scan action and took only one month. Waternet used the results of the quick scan to have arguments to start a program to make Amsterdam rainproof. With help of the results of the quick scan analysis the program (conveniently called: Amsterdam Rainproof) started in 2014.

Furthermore, the maps were used by Waternet and Amsterdam Rainproof to decide what locations to investigate further. Finally the maps are being used for education at the Amsterdam University of Applied Sciences.

The quick scan tool CLOUDS appears to be a valuable quick scan tool, which helps in a large city to decide where further research should be focused. Furthermore it helps to emphasize the importance of above ground measures to prevent flooding due to a cloudburst. In many cases simply looking at the ground level already gives valuable insight in the origin of water problems (where the water comes down the hill) and vulnerable locations (where it might flow to). Solutions are often evident yet the CLOUDS tool helps to visualize what is known.

For a climate resilient urban design it is needed that the above ground is shaped in a water sensitive way – so that at an extreme event water doesn't cause flooding of premises. This is not the work of the water engineer or specialist at the sewer department. This should be the work of all those shaping the urban space: water department, road department, green department. But also architects and urban planners should see understand this. A quick scan tool showing the ground levels can really help in achieving this.

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